

Toxic shockers: Key chemicals to look out for

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From BPA to burnt toast, pretty much everything in the modern world comes with a hidden cocktail of chemical extras. Get the facts on what to worry about.

TAKE a bite out of a fresh apple: there's nothing as healthy or natural. The problem is that science tells us otherwise: sensitive tests reveal that pretty much everything in the modern world – fresh fruit included – comes with a cocktail of chemical extras.

Some of these extras are welcome, but others are not. Consider that apple. In a study by the US Department of Agriculture, almost every apple tested contained residues of insecticides, fungicides and herbicides. Look hard enough and it is much the same story whichever food you examine.

Nor is it just our eating habits that expose us to these pollutants – we pick up tiny doses from cosmetics and paper, from the cushions and fabrics we sit on, the water we drink and the air we breathe.

Before you choke on your snack, bear in mind that most of these doses fall well below the levels considered harmful by regulators, while others don't have any discernible effect on the human body. But there are a few whose safety is disputed both by experts and in the popular press.

Here we explain what we know about nine of the most frequently suspected substances.

Antimicrobials

Want to keep your mouth fresh, armpits smelling sweet and feet fungus-free? Triclosan's antimicrobial clout has a wide reach: it is added to many products including soap, toothpaste and cosmetics. But in 1998, a report suggested that triclosan might be contributing to antibiotic resistance. Then in 2007, concerns emerged that the antimicrobial might alter hormone regulation in rats. Triclosan has since been scrutinised closely by regulatory bodies and scientists globally.

The concern in the rat studies was that triclosan disrupted the endocrine system – in particular thyroid function – when the rats were fed high doses of the stuff. Animal models don't necessarily translate to humans. However, the US Environmental Protection Agency (EPA) is keeping a close eye on triclosan's potential health effects: it has brought forward its scheduled review by 10 years. The EPA reports that there is a low-level risk to some aquatic life, particularly algae, from water that has triclosan in it. There are even indications that triclosan may not make hand-washing more effective – a number of manufacturers, among them Johnson & Johnson and Procter & Gamble, decided to eliminate the ingredient from their products. This year, Minnesota became the first US state to legally restrict its use.

In Europe, the question of antibiotic resistance is still being investigated. The European Commission's Scientific Committee on Consumer Safety says that triclosan is still safe to use, but admits there are gaps in knowledge.

Verdict: There's no direct evidence that triclosan damages human health, but it's under close scrutiny.



OF 5.7 MILLION TONNES OF POLLUTANTS RELEASED IN NORTH AMERICA:

- 1.8 MILLION TONNES CONSIDERED PERSISTENT, BIOACCUMULATIVE OR TOXIC
- 970,000 TONNES KNOWN OR SUSPECTED CARCINOGENS
- 857,000 TONNES CONSIDERED REPRODUCTIVE OR DEVELOPMENTAL TOXICANTS

(UNITED NATIONS ENVIRONMENT PROGRAMME)

Stain resisters

We owe the delights of nonstick cookware, waterproof clothing, stain-proof carpets and even dental floss to perfluorinated chemicals (PFCs), first produced industrially in the 1940s. These substances are marvellous at repelling grease and water, but a number of studies show that we all carry traces of them in our blood.

Two of the most common PFCs found in humans and the environment are perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). Thanks to their long molecular backbones and super-strong carbon-fluorine bonds, these chemicals are remarkably difficult to break down and so they persist in the environment for years. Animal studies suggest that long-chain PFCs may alter hormone levels and cause cancer. Human studies suggest that these chemicals may lead to thyroid disease and raised cholesterol levels among other things.

In 2009, PFOS was added to the list of chemicals banned under an international environmental treaty called the Stockholm Convention on Persistent Organic Pollutants. Eight major manufacturers have signed up to a US Environmental Protection Agency programme to eliminate the use of PFOA by 2015.

Manufacturers have also switched to shorter-chain PFCs, which should degrade more easily. Yet these chemicals are also a cause for concern. Take perfluorobutane sulfonate (PFBS). This is broken down in our bodies in days, so experts had not expected it to accumulate inside us. Yet a 2012 Swedish study found that the concentration of PFBS is increasing dramatically in our blood, doubling every six years – although concentrations remain relatively low.

There are other mysteries to solve. While the levels of PFOS and PFOA in blood are falling, PFOA concentrations have not declined as much as predicted. Scott Mabury at the University of Toronto in Canada suggests that might be because other fluorinated chemicals are converted to PFOA in our bodies. Chemicals called polyfluoroalkyl phosphate esters, widely used in greaseproof food wrappers, could be one source, he says. These chemicals have been detected in human blood, and animal studies suggest they can transfer from packaging into food.

Worse, Mabury says that tests on blood reveal a number of organofluorine compounds of which almost half cannot be identified. "This suggests there are new chemicals on the market that we have not measured yet."

Verdict: A widespread, persistent family of chemicals with evidence of impact on human health.

Fire fighters

Making furniture and fabrics resistant to fire seems like a no-brainer. Yet many flame-retardant chemicals pose a serious risk to health.

One group – the polybrominated diphenyl ethers (PBDEs) – comes in hundreds of forms, from penta- to decabrominated diphenyl ethers. Until recently, these substances were used in a vast array of products, from electronics to bedding. Many have now been banned or withdrawn in the EU and the US over concerns about reduced fertility and impaired development in children.

However, concentrations of PBDEs in people in North America have doubled every five years since the 1970s, and relatively high levels are found in house dust.

How the chemicals escape from furniture "is still a big unknown", says Heather Stapleton, an expert on flame retardants at Duke University in Durham, North Carolina. They may get into air pockets in cushions, she says, and enter the air when someone sits down. Foam can also rub off to form dust, she adds.

Linda Birnbaum, director of the US National Institute of Environmental Health Sciences in North Carolina, is particularly worried by another chemical called tetrabromobisphenol A (TBBPA), which has largely "fallen under the radar" despite being used in phenomenal quantities worldwide.

Research from the US National Toxicology Program showed that TBBPA causes cancer in rodents. There is also evidence that the chemical is an endocrine disruptor, affecting both thyroid hormones and oestrogen signalling, says Birnbaum. She has found that TBBPA can inhibit an enzyme that metabolises oestrogen, leading to elevated levels of the hormone in the body.

TBBPA is often used as a substitute for the banned deca-BDE, primarily in electronics, but too little is known about the new chemicals replacing banned retardants, says Birnbaum. "For some of the chemicals, what little information we have is very concerning," she says.

Take chlorinated tris (TDCPP), which was banned from use in children's pyjamas in the 1970s after it was found to cause cancer in animals. This chemical is still used in furniture, often as a replacement for penta-BDE.

Verdict: Harmful, banned retardants remain widespread. New ones may need more testing. ED

Cosmetics

In 2004, journalists and consumers got in a spin over chemical preservatives called parabens, when a study suggested that parabens were present in 20 breast cancer tissue samples, and linked the disease to cosmetics such as deodorants (Journal of Applied Toxicology, vol 24, p 5).

This sparked a long-running debate about the safety of parabens. But proof linking them to breast cancer has been elusive, and regulatory bodies, including the US Food and Drug Administration and the European Union's Scientific Committee on Consumer Safety maintain that, although parabens are thought to disrupt the endocrine system, the low doses in cosmetics are safe. What's more, most underarm deodorants don't contain parabens.

In 2012, another study into the link between parabens and breast cancer from the same researchers prompted UK charity Breakthrough Breast Cancer to speak out. "This research has serious flaws and provides no proof to suggest that women should be concerned about parabens."

Alan Boobis, director of the Public Health England Toxicology Unit at Imperial College London, agrees: "Parabens really aren't very harmful," he says. Animals exposed to "really quite high" levels experience no adverse effects, he says. "That is a consistent finding."

Despite a lack of pressure from regulatory bodies, cosmetics companies have started to remove parabens and other chemicals from their products. "It's because of public pressure," says Boobis.

Verdict: There's no convincing evidence that parabens in cosmetics damage human health. KS

Plastics

Phthalates are often added to plastics to increase their flexibility, but also turn up in a huge variety of other places, from pill coatings to printing inks. As a result, low levels of this group of chemicals are found in almost all of the people tested by the US Centers for Disease Control and Prevention.

Bad news? They have been identified as possible disrupters of the human endocrine system, but their health effects at low concentrations are unclear. Exposure at high levels is linked to lower sperm count and anatomical deformities in newborns, although this link has also been seen in groups exposed to regular levels of phthalates. "Our knowledge of phthalates largely comes from animal studies," says Laura Vandenberg at the University of Massachusetts, Amherst.

Verdict: Phthalates' effects on human health are unclear, but they are so widespread that they are difficult to avoid.

Metals

There might be no lead in vehicle fumes nowadays, but it is still getting into our bodies. "Lead is re-emerging as a problem," says Alan Boobis, director of the Public Health England Toxicology Unit at Imperial College London.

Lead exposure has dropped dramatically since the 1970s, especially in the EU after it was banned in petrol and regulated in pipes and paints. But all the lead that has been released over the years has made it into the soil, and so we end up eating it in our food. The main culprits are cereals, with vegetables and tap water also contributing. Avoiding lead is virtually impossible.

In 2010 the European Food Safety Authority (EFSA) reduced its recommended threshold for lead in the body, and concluded that a measure that used to be called a provisional tolerable weekly intake was no longer appropriate. "There is no safe blood lead level," says Boobis. "Even at low levels, lead seems to be associated with lower IQ," he says. Babies and children are most at risk.

Mercury too, remains a concern. Unlike lead, mercury accumulates in the food chain and top-predator fish are our main dietary source. Too much mercury can result in developmental damage in babies and small children. A new study shows that mercury levels have tripled in surface waters, especially around Iceland and Antarctica, yet this represents just a quarter of the total amount released by industry. The rest, researchers suggest, is probably in ocean sediments.

The one place where mercury is closest to us is possibly the place where we should fear it least: mercury amalgam tooth fillings. "The amount of mercury that comes out is so low it has little effect," says Boobis.

Verdict: Guilty as charged. Mercury intake can be reduced by avoiding predatory fish. KS

Pesticides

Many pesticides are designed to poison nervous systems, but toxicologist Rudy Richardson at the University of Michigan School of Public Health in Ann Arbor says we shouldn't worry too much: these neurotoxins are not wantonly sprayed on our food. "These compounds are probably the most strictly regulated of all types of chemical substances." Yet even regulators don't always agree on risks – the herbicide atrazine, for example, is banned in the EU but widely used in the US.

Traces of pesticides are now widespread in the environment. The US Centers for Disease Control and Prevention has shown that most Americans have very low concentrations of organophosphate pesticides in their urine, and surveys by the US Department of Agriculture have found that many kinds of fruit and vegetables contain tiny amounts of pesticide residues. Although these are below levels deemed dangerous by regulators, pesticide use is on the up. This worries environmental scientist Laura Vandenberg at the University of Massachusetts, Amherst. "Pesticides are designed to be biologically active," she notes.

Studies link exposure to organophosphate pesticides in pregnancy to delays in childhood development and autism, and suggest they may also play a role in cardiovascular disease. A review of epidemiological studies published in *The Lancet Neurology* suggests that a common organophosphate pesticide, chlorpyrifos, can damage human brain development (vol 13, p 330). And according to Linda Birnbaum, director of the US National Institute of Environmental Health Sciences in North Carolina, there is evidence that pesticide exposure may increase the risk of developing diabetes and obesity.



TESTS SHOWED 12,000 OUT OF 77,000 SAMPLES FROM 500 DIFFERENT FOODS CONTAINED PESTICIDE LEVELS EXCEEDING EUROPEAN LEGAL LIMITS

(EUROPEAN FOOD SAFETY AUTHORITY)

In 2012, the EU completed a review of 1000 pesticides that led to the withdrawal of about 700 older chemicals from the market. The US Environmental Protection Agency has a programme to speed up the registration of new, safer alternatives to older pesticides.

Verdict: Pesticides can be harmful, but are very tightly controlled. KS

Burnt food

Your morning coffee and toast, it seems, could be hurting you. In 2002, Swedish researchers reported that acrylamide, a chemical linked to cancer in rodents, is present in some cooked foods at surprisingly high levels.

Acrylamide forms when plant-based foods rich in carbohydrates are baked, fried or roasted at high temperatures. The chemical is created as part of a browning reaction involving sugars and an amino acid called asparagine, and adds to a food's appeal by creating flavour and colour. Since acrylamide is highly water-soluble, it is absorbed from the gut and then distributed to tissues. Animal studies suggest that acrylamide has the potential to cause cancer, possibly by forming a substance called glycidamide in the body, which is widely distributed into tissues.

According to the European Food Safety Authority (EFSA) Panel on Contaminants in the Food Chain – which has pored over vast numbers of studies – foods such as chips, breakfast cereals, biscuits and breads all contain acrylamide. Its draft report, released for consultation in July 2014, states that eating acrylamide "potentially increases the risk of developing cancer" and reveals that coffee and fried or roast potatoes are the worst offenders.

Some research also links the chemical to effects on the nervous and reproductive system in rodents. A recent study by a collaboration between the Norwegian Institute of Public Health and Stockholm University suggests that pregnant women exposed to higher levels of acrylamide had smaller babies. Yet the EFSA makes it clear that studies have "not demonstrated acrylamide to be a human carcinogen".

That hasn't prevented a lawsuit in the US claiming that food manufacturers had failed to warn consumers about the dangers of acrylamide. As a result, acrylamide must be labelled in consumer products in California and some manufacturers have agreed to reduce levels of the chemical in their foods.

Unfortunately, acrylamide is nigh on impossible to avoid if you enjoy tasty, starch-rich foods. But there are ways to limit consumption. Toast can be eaten golden rather than darker brown, and research has shown that a short espresso has less acrylamide than a lungo, which takes twice as long to prepare.

For now, the EFSA recommends avoiding overcooking and excessive crisping. "Don't burn it, lightly brown it," goes the advice.

Verdict: Despite lingering concerns, acrylamide in food is not a confirmed carcinogen in humans.

Packaging

The coating of till receipts, food-tin linings and polycarbonate plastics all contain a synthetic oestrogen that has been mired in controversy for more than a decade. That's because the compound, the plasticiser bisphenol A (BPA), has the potential to influence hormonal systems in mammals.



After tests by the US Centers for Disease Control and Prevention found BPA in more than 90 per cent of Americans, and the US National Toxicology Program expressed concern over its effects on the brains and behaviour of young children, the Food and Drug Administration banned the chemical from babies' bottles in 2012.

In Europe, a similar ban came into force in 2011, and the committee for risk assessment at the European Chemicals Agency, which advises EU regulators, announced that BPA is a "presumed human reproductive toxicant". Yet while BPA's impact has been confirmed in animals, its action is hard to prove in humans, in part because our bodies rapidly convert it to a form that exhibits no oestrogen-like activity.

While some researchers and campaigners argue that current safety levels are not stringent enough, attention is turning to BPA's replacement, bisphenol S. This has a similar structure and one study says it may also act like oestrogen.

To reduce your exposure, says Laura Vandenberg at the University of Massachusetts, Amhurst, you should lay off canned food. Avoid thermal-paper till receipts too, she says, and don't heat foods in plastic containers.

BPA is just one of many potential "endocrine-disrupting" chemicals we are exposed to. In 2013, 85 scientists signed a document demanding tougher regulation in Europe. The Berlaymont Declaration on Endocrine Disrupters pointed to rising levels of cancer, plus brain, thyroid and reproductive problems, and suggested that the rate of increase in endocrine-related diseases cannot be explained by genetics or lifestyle alone.

Verdict: BPA may be just one of many endocrine disrupters damaging human health. ED

Up to our necks in Chemicals

Understanding the risks posed by additives and contaminants seems like a mission impossible. For a start, most chemicals are only tested in animals, and then at high doses, so their impact on humans isn't clear. At the same time, industries make and use synthetic chemicals in so many different forms that without a step change in the way we assess them, there is little chance of quantifying the risks they pose, says Julian Cribb, an Australian journalist and author of *Poisoned Planet*. Even the exact number of chemicals marketed globally is unknown, he says. One guide is the number registered with the EU – which stands at around 144,000. Of these, roughly a third are thought to be harmful, says Cribb, but "the vast majority have not been assessed for human or environmental safety".

And there are other challenges. The chemicals industry is set to triple in size by 2050, with manufacturing shifting from North America and Europe to nations in Asia and South America. Many of these places currently lack robust safety regulations.

There have been some successes in the long-term clean-up of our environment. Many countries no longer use asbestos or tetraethyl lead, and the Stockholm Convention lists 25 nasties that are banned or being eliminated from use, including DDT, dioxins and PCBs. Others are under review. Yet this list represents "just a few pixels in a megapixel image of global toxicity", Cribb warns. "At the current rate it will take around 50,000 years to assess the remainder."

Scientists have begun to plot a course of action to tackle this task more swiftly. In the US, for instance, the Toxicology in the 21st Century (Tox21) programme aims to make testing faster and cheaper.

Created by the National Institutes of Health, the Environmental Protection Agency and the Food and Drug Administration, Tox21 aims to examine how 10,000 different chemicals affect human health. To do this, it will use high-throughput screening – made possible by robotics and powerful computers – to run huge numbers of chemical tests. Computers can then seek patterns that reveal

how chemicals disrupt pathways in human cells, and gauge their impact on human health. "This will allow us to make decisions without extensive animal testing," says Linda Birnbaum, director of the National Institute of Environmental Health Sciences in North Carolina.



**IN 2004, 4.9 MILLION DEATHS WERE ATTRIBUTABLE TO EXPOSURE TO
SELECTED CHEMICALS**

(WHO)

This strategy offers another benefit. It could reveal if tiny amounts of toxic chemicals interact with each other to make us ill – the so-called "cocktail effect". This question has troubled experts for many years. Conventional tests examine one chemical at a time, but in the real world we face mixtures of chemicals at doses below those usually thought damaging, such as in vehicle exhausts and cosmetics. Yet there is good evidence for an additive effect in which minute amounts of, say, endocrine disrupters can act together to do harm. The European Commission is in the process of identifying which combinations should be assessed as a priority. Along with high-throughput screening, this may finally offer a way to navigate the complexities of chemical safety. "My hope is that within 10 years we'll be able to make decisions based on Tox21," says Birnbaum.